ADVANCED AUTOMOTIVE PISTON ENGINES-
COMBUSTION R&D

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ABSTRACT

Sandia National Laboratories/California has had two technical projects supported by the Department of Energy/Office of Transportation Technologies. They are entitled: (1) Fuel/combustion system optimization and (2) Cylinder design for reduced emissions. These projects were conducted jointly with Los Alamos National Laboratory and Lawrence Livermore National Laboratory, respectively. A third project, compression-ignited, direct-injection diesel, was begun late in the fiscal year and is a collaboration with the Univeristy of Wisconsin, Madison and Wayne State University. Each project area is conducted under a cooperative research and development agreement (CRADA). This report summarizes the project areas. Details regarding each specific project can be obtained during the poster session.

INTRODUCTION

The projects reported in this paper directly support the U.S. automobile manufacturers and the Partnership for a New Generation of Vehicles (PNGV). The objective of each project is briefly described and is followed with a table showing the participants. Significant results have been obtained in the fuel/combustion system optimization and cylinder design for reduced emissions areas. These projects have been ongoing for two years and been conducted under the auspices of cooperative research and development agreements (CRADAs) with the U.S. automobile companies. The third project reported on here, compression-ignition, direct-injection diesel, only started in September 1996. This latter work is also being conducted as a CRADA but no results have been obtained as yet because it is a new start.

Fuel/combustion system optimization

The objective of this work is to develop new diagnostics and computational submodels to characterize and optimize fuel delivery into the cylinder of an automobile engine. Optimized air/fuel mixture quality is critical to engine performance, efficiency, and emissions. This is particularly true during cold start and, to a lesser degree, warm transients. There is work currently underway within the automotive industry to characterize the port injection process in steady-state flow rigs, including measurements of spray pattern and footprint, droplet size, and droplet velocity. These characterizations are then used to seek correlations with engine performance measurements obtained on dynamometer test stands. The work in this project area bridges these two test environments by providing detailed measurements of the air/fuel quality in the cylinder of both motored and fired engines. Of particular emphasis will be determination of the relationship between the port injection process and the air/fuel distribution in the combustion chamber at the time of ignition. In addition, submodels to describe wall-wetting, fuel film growth and motion, film heat transfer and boiling, and droplet entrainment are being developed and implemented in full 3-dimensional computational fluid dynamic codes.

Lab/University	Principal Investigator	Project Title
Los Alamos Nat'l Lab	T. Daniel Butler	Spray Modeling
Sandia Nat'l Labs	Peter O. Witze	Fuel/Combustion System Optimization

Cylinder design for reduced emissions

The objective of this project area is to apply advanced diagnostics and computational modeling techniques to characterize the in-cylinder processes leading to hydrocarbon emissions and post-combustion oxidation. This work is being conducted because the automobile industry faces more stringent regulations in the coming years due to mandated limits in permitted levels of emissions of a wide range of hydrocarbon and partially-oxidized, hydrocarbon species. Meeting these emission levels may require significant improvements in automobile engines and modifications in the composition of the gasoline fuels burned. These advances in the engine and fuels technologies will require a great deal of research and development effort.

The primary source of unburned hydrocarbon species emitted from engines is due to fuel and air trapped in confined volumes in the combustion chamber, particularly the ring crevice between the piston and the cylinder wall. In this confined volume, heat transfer to cylinder and piston surfaces cools the gases and impedes their consumption by flame propagation. After normal flame propagation is complete, these gases escape from the crevices, mix with combustion products, are partially burned and then leave the combustion chamber along with the exhaust gas. Other sources of unburned hydrocarbons include fuel adsorbed by oil layers and deposits on the interior surfaces of the cylinder, regions of dilute mixture where the oxidation reactions are slow, and boundary layers near cool surfaces where heat transfer can cool the gases, reducing the reaction rates. This research program uses an experimental approach coordinated with computational modeling to examine interactions between fuel composition and engine operating parameters, and emissions from the engines.

Lab/University	Principal Investigator	Project Title
Lawrence Livermore	Charles Westbrook	Engine Combustion Chemistry Modeling
Sandia Nat'l Labs	Robert Green	Cylinder Design for Reduced Emissions

Compression-ignition, direct-injection diesel

The objective of this work is a combined fundamental experimental research and computational modeling effort to investigate the in-cylinder processes in a small-bore, direct injection diesel engine. The PNGV goal of producing an 80-mile-per-gallon automobile with a 400 mile cruising range requires significant technological advances in many areas. One of the most critical components is the engine itself. Of all possible engines, a high-speed, small-bore, direct-injection (DI) diesel engine is the strongest candidate. These engines offer high thermal efficiency, have demonstrated reliability, and are compatible with projected PNGV vehicle designs including both proposed hybrid-electric and high-efficiency mechanical drive trains. In addition, they have considerable potential for further improvements in performance, fuel economy and emissions, and the potential for meeting the PNGV cost and time frame goals.

The current state of the art for small-bore DI diesels are those found in European passenger cars. Although first introduced only a few years ago, these DI diesels are making rapid inroads into the European diesel passenger car market (10% currently and 50% expected by the year 2000). This market had previously included only the less efficient indirect injection (IDI) diesel. While the DI diesels are a significant improvement over the IDI type, their performance and emissions are still well short of PNGV goals. For example, the Volkswagen Passat (a mid-sized car) with a DI diesel is EPA rated at 45 mpg (highway), with emission levels that exceed PNGV targets. The second-generation European DI diesels (available next year) are expected to be a little better; however, significant improvements in fuel economy, performance, and emissions are still possible and are required to meet PNGV goals.

Achieving the PNGV goals will require advances in many areas, including: the design of the fuel-injection/combustion systems and control of emissions in-cylinder; exhaust aftertreatment; turbochargers; engine architecture, materials, and controls; and potentially fuels. Among these, the design of the fuel-injection/combustion system and the associated control of emissions in-cylinder are two of the most critical. The current knowledge base in these two critical areas is inadequate, and a research program is required to develop the understanding necessary to meet the PNGV goals. This research has a very high payoff potential by helping PNGV meet its immediate goal of an 80 mile-per-gallon automobile by 2004; moreover, it offers the possibility of continued improvements beyond that time.

Lab/University	Principal Investigator	Project Title
Sandia Nat'l Labs	Paul Miles	CIDI Combustion Processes in an Optically Accessible Engine
University of Wisconsin	Rolf Reitz	Computer Modeling of Combustion and Emissions in Small DI Compression Ignition Engines
Wayne State University	Naeim Henein	Investigations of Performance and Emissions in a CIDI